HUMIDIFYING AIR IN LIVING ROOMS
BY
ATTACHMENTS TO THE STEAM RADIATOR
BY
G. L. ANDRE

ARMOUR INSTITUTE OF TECHNOLOGY
1918

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HUMIDIFYING AIR IN LIVING ROOMS BY ATTACHMENTS TO THE STEAM RADIATOR

A THESIS

PRESENTED BY

GUY L. ANDRE

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

MAY 29, 1918

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PREFACE

In presenting this work, the writer desires rather to diagnose the problem of properly humidifying the air in living rooms, than to offer a specific appliance by means of which this can be accomplished. It is admitted that the apparatus, as constructed by the writer, for this purpose, is in itself not sufficient for the purpose intended, nor practical for ordinary use.

The subject matter has been divided into four parts and a brief summary. In Part One, the necessity for artificial humidification in living rooms is discussed, and some of the effects of lack of sufficient moisture are shown. In Part Two are shown the results of tests on all of the principal humidifiers on the market, showing that not one of them accomplishes the results for which it was intended. In Part Three, the problems entering into the humidification of rooms are discussed, and

a problem in fuel economy with humidification is worked out. In Part Four, the design of a proposed humidifier is shown, its short-comings cited, and suggestions made for the design of other humidifiers.

The writer has confined himself to the problem of humidfying by means of attachments to the steam radiator, believing that a greater number of living rooms are heated in this manner than in any other. He admits that the problem can be easily solved, if constant care can be given the humidifier, but this is possible in very few instances, and any apparatus to be entirely satisfactory must be made to operate automatically.

The writer is indebted to Prof. G. F. Gebhardt for many of the ideas of design, and to Prof. R. W. Perry for numerous helpful suggestions as to methods of calculations.

- PART ONE -

The necessity for artificial humidification of living rooms during the winter months.

Introduction.

It is coming to be recognized more and more by engineers and physicians, that the humidity of the air in rooms has a great deal to do with the problems of ventilation of the rooms and the health of the individuals living in them. It is deemed expedient therefore, to devote some little space to a discussion of some of the needs of humidification, and some of the results of failure to provide proper moisture in living rooms.

PART ONE.

By the word "humidity" is meant "moisture," and in speaking of the humidity of a room, we mean the amount of moisture in the air in the room. The actual amount of moisture is the absolute humidity, and the actual amount of moisture in the room, relative to the amount of moisture that is necessary to saturate the air at the temperature of the room, is termed the relative humidity of the room. There is quite a difference of opinion as to the proper amount of relative humidity that a room should contain, but it is generally agreed that it should be somewhere between 40% and 60%. A high percentage of relative humidity is as objectionable as a low humidity. This will be readily admitted, when we think of the depression felt on the hot days of summer when the air contains much moisture. A similar feeling is experienced on entering a room where damp clothes have been hung to dry. On the

other hand, all of us have noticed the dryness of the air in some poorly ventilated rooms in the winter time. The air passages in the nose become dry and parched, and there is a feeling of not being able to get air enough. This is caused by the small amount of moisture in the air. The lower the temperature of the air, the less moisture it will take to saturate it. The table below will show the amount of moisture necessary to saturate 1000 cu. ft. of air at various temperatures.

Temperature	100°	2.85 lbs. cu. ft.
"	90°	2.137 "
"	80°	1.58 "
"	70°	1.153 "
"	60°	.823 "
"	50°	.588 "
"	40°	.41 "
"	30°	.278 "
"	20°	.177 "
"	10°	.11 "
"	0°	.067 "

A glance at this table will quickly show why it is necessary to moisten artificially the air in our living rooms during the winter months. For instance, consider air at an outside temperature of 20° F. which is a fair average for a winter day. Referring to the table, 1000 cu. ft. of air at a temperature of 20° contains .177 lbs. of water vapor when saturated. For an average day, the air would, of course, not be saturated, but would have a relative humidity of say 60%. Then 60% of .177 gives .1062 as the actual amount of water vapor that the air contains at that temperature. Now, consider that 1000 cu. ft. of air are drawn into a living room, which is heated up to a temperature of 70° - what happens? According to the laws of Boyle and Charles:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

where,

P_1 = initial absolute pressure lbs. per sq. ft.

V_1 = initial volume cu. ft.

T_1 = initial absolute temp. deg. fahr.

P_2 = final absolute pressure

V_2 = final volume

T_2 = final temperature

substituting values,

$$\frac{29.9 \times 1}{460 + 20} = \frac{29.9 \times V_2}{530}$$

$$V_2 = 1.1$$

That is, the volume of air coming into the room has increased from 1000 cu. ft. to 1100 cu. ft. Then, the amount of moisture per 1000 cu. ft. is equal to

$$.1062 \times \frac{1}{1.1} = .0965 \text{ lbs. per cu. ft.}$$

Now, consider the difference in the amount of moisture that it will take to saturate 1000 cu. ft. of air at these two temperatures. At 20°, 1000 cu. ft. of air contain .177 lbs. of water vapor, while at a temperature of 70°, (the temperature to which the air in the room becomes heated,) it takes 1.153 lbs. of water vapor to saturate 1000 cu. ft. of air. Suppose we desire to have the air in the room at a relative humidity of 50%. Then 50%

of 1.153 gives .576 lbs., as the weight of the moisture in the air for the desired humidity. Referring back to the amount of moisture that we have in 1000 cu. ft. of air entering the room from an outside temperature of 20°, we see that it is necessary to add an amount of moisture equal to .576 - .0965, or, .48 lbs. for every 1000 cu. ft. of air in the room in order to get a humidity of 50% at a room temperature of 70°.

Taking the figures above, we find that if there is absolutely no moisture added to the air the humidity of the room under the conditions named will be $\frac{.0965}{.576} = 16.9\%$

If air is taken in at a lower temperature than 20°, a greater amount of moisture will have to be supplied in order to bring the air to a satisfactory condition. However, air taken in at a low temperature and heated up to a higher one does not drop as low as the theoretical value obtained above, on account of the moisture taken up from the surrounding objects in the room. The

moisture is drawn out of the glue in the chairs, and even from the pores of the wood itself. This causes the wood to warp and crack, and the glue soon becomes nothing but a powder with very little of its former adhesive qualities. Everything that can give up any moisture is subjected to the drying influence of the air. The walls of the room, the flowers and the plants, and even the human body, give up a portion of their moisture. If we sit in a room of very low humidity, our skin begins to feel dry and parched, and our hands become chapped, if such a condition of the air exists continually. This excessive evaporation gives us a chilly feeling, and the dryness of the skin irritates the nervous system, making us more susceptible to disease germs. A low humidity is also detrimental to health on account of the number of dust particles floating in the atmosphere. The more moisture there is in the air the less dust there is; and the more dust, the more bacteria. According to Dr. Hill of the Chicago Bureau of Ventilation, a large amount of

dust shows bad air, and the ideal condition requires absolute freedom from dust. With his new dust counter, invented a few years ago, he is able to get a sample of the dust in the air, and he says; "The bacteria are counted by exposing a previously sterilized plate of gelatine to the air for two minutes. If this plate is allowed to stand for a few days, the bacteria will multiply so rapidly that on each spot where a single bacterium fell when the plate was exposed, a large number or colony of bacteria will develop. These bacteria being visible to the naked eye can be counted quite readily."

Perhaps one of the most important reasons for the humidification of rooms at the present time is the saving in fuel with high humidities. During the past year, on account of the scarcity of coal, the engineer has turned his attention to methods of saving every pound of coal possible, and of utilizing every B.t.u. available. Humidification has received

its share of attention, and many and varied are the devices put forth to increase the humidity in living rooms.

When the room has a low humidity, there will be, as shown in the preceding pages, an evaporation of moisture from the body to supply the dry air. This will create a chilly feeling, and it will be necessary to have an increase in temperature to have a feeling of comfort. Certain conditions of temperature may be ideal on one day and very uncomfortable on another, depending upon whether the humidity is high of low. For instance, a day that seems very close and "stuffy" when we are down town, may become nearly ideal, when we are riding in an automobile and the air is blowing rapidly over our body, evaporating the moisture from it and giving us a feeling of coolness and well-being. The same principle is involved in the electric fan. Thus it can be readily understood why a room may be kept at a temperature of 68° and a high humidity, and the inmates feel the

same degree of comfort and warmth that they would feel if the room were heated to a temperature of 72° with a low humidity. In very cold weather the difference of a few degrees in the temperature at which a room must be kept means a big difference in the amount of fuel used in the furnace, and with the price of coal soaring as it is, and the possibility looming up of not being able to get it at any price, a discussion of the ways and means of saving fuel, and the apparatus put forth to accomplish this saving, is, perhaps, not irrelevant.

- PART TWO -

Tests of apparatus designed
to attach to the steam radiator and
humidify the air in living rooms.

Introduction.

In making tests of this nature, it is nearly impossible to duplicate a set of conditions for all of the tests, but it is nevertheless necessary to have a certain standard set of conditions near which one should work. Accordingly, for the city of Chicago, it is assumed that the outside air should be at 0° F. and the inside air at a temperature of 70°. This is a condition that is generally accepted for this latitude, and although the tests, as made, are not always under these accepted conditions, the data obtained serve just as well for a comparative test of the various apparatus.

PART TWO.

Before working upon the construction of any apparatus designed to humidify the air, a test was made of all of the principal humidifiers on the market, in order to see to what extent the problem of humidifying had already been solved. The humidifiers tested were bought direct from the factories with no notice having been given the manufactures that any test was to be made, and the apparatus, as tested, was identically the same as that on sale at any of the department stores in the city. The four different kinds that were tested are:

Savo,

Eureka Blotter Bath,

Buddington,

Flobun.

In making the tests a radiator of the style shown on the next page was used.



Type of proposed humidifier.

This is a radiator made by the American Radiator Company, having 10 coils, a height of 1-1/2 feet, and 1-1/2 sq. feet of radiator surface. The first tests were made in the Fuel Laboratory of the Armour Institute of Technology. The room was 20'x18'x10', giving a volume of 3600 cu. ft. Low pressure steam was used direct from the return line of the Institute heating system, and a pressure of from 2 to 5 lbs. was maintained throughout the test. This is generally the pressure in most of the radiators, when exhaust steam is used for heating purposes.

The object of the test was to determine the amount of water evaporated per hour, per square foot of radiator heating surface, and also to get a record of the increase in the relative humidity in the room due to this evaporation of moisture. The room was kept at as even a temperature as possible by window ventilation near the ceiling, and the condensed steam pipe from the radiator was run to the sewer through a drain in the floor. In order that none of the steam from

the drain pipe would be evaporated into the air being tested, a round wooden block was made to fit tightly in the drain, and the drain pipe run through a hole in the wood. Everything was made a snug fit, so that there was no leakage. Conditions seemed to be about perfect for an ideal test, but at times it was found that steam from the engine room affected the air in the testing room, and that it was impossible to keep it out. For this reason the humidifiers would be given credit for evaporating more water than they actually evaporated, and the test would not show the exact capability of the apparatus to humidify the air, although the comparison between the different kinds of apparatus might be just as good. The Fuel Laboratory was in use a great deal of the time for other experiments, and the conditions were often disturbed. For these reasons, the test room was changed after the first few tests.

Following the picture of the Flobun Humidifier, shown on the next page, is the test made of it.

TEST OF A FLOBUN HUMIDIFIER

DECEMBER 28th 1917.

Time	Temperatures Dry	Wet	Diff.	Relative Humidity	Steam Pressure	Outside Temperature
12 M	64	59	5	75	5	12
1 PM	76	65	11	55	5	11
2.00	75	64	11	55	5	10
3.00	78	63	15	43	4	10
3.30	79	64	15	44	5	10
4.00	75	61	14	44	5	8
4.30	74	61	13	47	5	8
5.00	75	61	14	44	5	7
5.30	74	62	12	47	5	7
6.00	76	62	14	45	5	6

Water evaporated	1.554 lbs
Water evaporated per hour	.259 lbs
Water evaporated per hour per sq. ft. radiator surface	.17 lbs

TEST OF A LOBUT HUMIDIFIER.

January 3rd, 1918.

Time	Temperature Dry	Wet	Diff.	Relative Humidity	Room Temperature	Outside Temperature	Steam Pressure
10:30	80	64	16	41	82°	27°	5
11:00	65	53	12	44	70	27	6
11:30	69	55	14	40	72	28	6
12:00	69	56	13	44	70.5	28	6
12:30	70	58	12	48	71	26	5
1:00	76	62	14	45	73	26	5
1:30	66	53	13	41	70	25	4.5
2:00	74	60	14	46	74	23	6.5
2:30	75	60	15	43	76	23	6.5
3:00	76	60	16	38	77	21	6.5
3:30	69	54	15	36	70.5	21	6
4:00	68	54	14	39	70	21	6
4:30	67	54	13	42	70	20	4.5
5:00	65	52	13	40	68	20	4
5:30	65	53	13	40	68	19	4
6:00	65	52	13	40	69	18	4.5

Water evaporated 2.546 lbs
Water evaporated per hour 3.39 lbs
Water evaporated per hour
per sq. ft. radiator surface .113 lbs

The Buddington Humidifier is manufactured by the Reid-Geisler Manufacturing Co., Chicago, Ill., and is designed to fit on top of the radiator, being fastened in position by wires running under the radiator coils. It consists of a pan of the form shown in the picture on the following page. Wicks are soaked with water and are hung over the wires, as indicated, with one end in the water. The warm air from the radiator, passing up through the vents in the wings, produces the evaporation.

TEST OF BUDDINGTON HUMIDIFIER.

January 26th, 1918.

Time	Temperatures Dry	Wet	Diff.	Relative Humidity	Room Temperature	Outside Temperature	Steam Pressure Inlet	Outlet
9:00	69	59	10	55	70°	9°	30	5
9:15	70	60	10	56	73	9	30	5
9:30	70.5	60.25	10.25	56	73	9	30	5
9:45	73	63	10	58	75	10	42	10
10:00	73	62	11	54	75	11	42	5
10:15	73	62	11	54	76	11	42	5
10:30	73	62	11	54	76	11	42	5
10:45	68	58	10	55	74	12	55	5
11:00	68	57	11	51	73	12	38	5
11:15	67	57	10	54	70	13	45	5
11:30	67	54	13	41	70	13	45	5
11:45	68	55	13	43	72	14	45	5
12:00	68	56	12	47	72	14	45	5
12:15	68	55	13	43	72	15	45	5
12:30	68	55	13	43	71	14	45	5
12:45	67	55	12	46	72	14	44	5
1:00	67	54	13	42	73	13	46	6
1:15	67	55	12	46	73	13	48	6
1:30	68	55	13	43	72	13	50	7
1:45	69	56	13	44	71	13	50	6
2:00	69	56	13	44	70	12	50	5
2:15	68	55	13	43	70	11	50	5
2:30	68	54	14	39	71	11	50	5
2:45	67	55	12	46	72	11	50	5
3:00	67	55	12	46	72	11	50	5

Water evaporated	3.84 lbs
Water evaporated per hour	.64 lbs
Water evaporated per hour per sq. ft. radiator surface	.21 lbs

The Eureka Blotter Bath Humidifier was tested out under a little different condition. In this case the room was 29-1/2'x 16-1/2'x11-1/2', giving a volume of 5529 cu. ft. This room is located in the southeast corner of the basement of Machinery Hall, and is the room formerly used as the office of the Mechanical Department. High pressure steam was used in this case, and the pressure was reduced to that of the ordinary radiator by two valves. A pressure gauge was placed between the two valves, and one on the radiator near the point where the condensed steam left. Both valves were just cracked off their seats enough to give a pressure of about 5lbs. in the radiator.

This humidifier is of the form shown on page 31 and is suspended by hooks, so that it rests along the side of the radiator. It consists merely of a sort of soap stone supported in a can of water. The stone extends above the top of the water level in the tank,

and the water is drawn up in the wick strip, in the same manner that it is absorbed by a sponge. This gives a larger evaporative surface than would be obtained by the tank of water alone. The radiator used in this case was of the following dimensions: 2'5" breadth, 2'10" heighth, 7-1/2' width, made by the American Radiator Company and having 3 sq. ft. of heating surface.



TEST OF EUREKA BLOTTER BATH HUMIDIFIER.

February 2nd, 1918.

Time	Temperatures Dry	Wet	Diff.	Relative Humidity	Steam Pressure Inlet	Steam Pressure Outlet	Average Room Temperature	Outside Temperature
8:15	66	50	16	29	80	5	68	6
8:30	65	48	17	25	60	5	70	6
8:45	63	47	16	26	60	5	70	6
9:00	64	48	16	27	65	5	70	6
9:15	63	47	16	26	50	7	71	7
9:30	63	47	16	26	44	5	71	8
9:45	65	47	18	21	63	10	71	9
10:00	65	47	18	21	58	4	71	9
10:15	66	48	18	22	62	8	71	10
10:30	66	48	18	22	60	4	72	11
10:45	66	48	18	22	60	4.5	72	12
11:00	67	49	18	23	65	5	72	12
11:15	67	49	18	23	55	3	72	12
11:30	67	49	18	23	54	10	69	12
11:45	66	47	19	18	50	5	69	14
12:00	66	47	19	18	50	5	69	14
12:15	67	47	19	20	52	4	69	14
12:30	67	48	19	20	50	4	70	13
12:45	67	48	19	20	50	5	70	13
1:00	67	48	19	20	48	5	70	13
1:15	66	47	19	18	48	6	70	13
1:30	65	48	17	21	50	6	70	13
1:45	66	47	19	18	54	7	70	12
2:00	65	47	18	21	54	7	71	12
2:15	65	47	18	21	54	6	71	12
2:30	65	47	18	21	56	5	71	11
2:45	65	47	18	21	56	5	70	11
3:00	64	48	16	27	55	5	70	10
3:30	64	48	16	27	55	5	70	10
3:45	63	48	15	30	55	6	70	9
4:00	64	49	15	31	55	6	69	9
4:15	65	49	16	28	56	5	69	8
4:30	65	49	16	27	56	6	69	7
4:45	66	49	17	26	58	5	69	6
5:00	66	49	17	26	58	5	69	6
5:15	66	49	17	26	58	5	69	6

Water evaporated 2.366 lbs
Water evaporated per hour .2629 lbs
Water evaporated per hour per sq. ft. radiator surface .0876 lbs

The next test was run on the Savo Humidifier, under the same conditions that were applied to the Eureka Blotter Bath. The Savo Air Moistener is shown on the following page, and is manufactured by the Savo Manufacturing Co., Chicago, Ill. The style tested out in this case was their style No. 1, which is 14 in. high and 12-1/2 in. wide. It consists merely of a can of water supported along the side of the radiator. The inner side is made in a triangular shape in order to get a larger contact surface, and aside from this feature, it differs in no way from an ordinary can of water hung along the side of the radiator.

Savo Air Moistener.

TEST OF SAVO HUMIDIFIER.

March 29th, 1918.

Time	Temperature Dry	Wet	Diff.	Relative Humidity	Room Temperature	Steam Pressure	Outside Temperature
8:30	68	52	16	31	71°	5	38°
9.30	71	54	17	30	72	5	38
10:30	71	54	17	30	73	5	39
11:30	71	54	17	30	72	5	40
12:30	74	55	19	27	74	5	41
1:30	72	53	19	27	72	5	41
2:30	72	53	19	27	72	5	40
3:30	73	54	19	26	73	5	40
4:30	72	54	18	28	72	5	38
5:30	72	54	18	28	71	5	38

Water evaporated 1.21° lbs.

Water evaporated per hour .202 lbs.

Water evaporated per hour per sq. ft. of radiator surface .067 lbs.

The results of the four different tests show that of the four humidifiers tested the Buddington gives the greatest amount of evaporation per hour per sq. ft. of radiator surface. The different amounts are shown below:

Humidifier	lbs. water per hr. per sq. ft. rad. surface
Buddington	.21
Flobun - 1st test	.113
2nd "	.17
Eureka Blotter Bath	.0876
Savo	.067

However, a glance at the test sheets shows that the amount of moisture evaporated did not cause an increase in the relative humidity of the room, as recorded by the psychrometer. In many cases there was an apparent decrease in the humidity. In general, the tests showed that as far as humidifying the air in the rooms was concerned, all of the apparatus tested was practically worthless. In Part Four the writer will show that the amount of water evaporated by any

of them was far short of the amount necessary to raise the humidity of the room to the desired percentage.

Dr. F. P. Lyon of the University of Minnesota made some experiments during the year 1916 on three different humidifiers: the Buddington, the Flobun and the Savo. His results vary a little from those obtained in the tests as shown above, but lead to the same conclusion: that the apparatus is grossly inadequate for the purpose intended. The results of his tests are shown below. It will be noticed that he has given the amount of evaporation for each of the humidifiers for 24 hours for each horizontal foot of radiator surface occupied by the apparatus:

Buddington	1116 grams	(zero weather)
Flobun	1248 "	"
Savo	230 "	"

In his report of the tests he says; "No noticeable increase in the humidity was obtained, using a sling psychrometer for the determination."

In a recent test in a Public School room, it was found that the average evaporation

of moisture from one person (lungs and skin) was 2 oz. per hour. Comparing this amount with the amount which we found by test was evaporated by the humidifiers, we find very little difference. The evaporation of the humidifiers, when reduced to ounces per hour, reveals the fact that two or three people in a room humidify the air as much as any of the patent apparatus on the market.

Other experiments, according to Harding & Willard, give the following as the amounts of vapor given off:

Man at work	.367	lbs. per hour
Man at rest	.155	" " "
Youth	.085	" " "
Infant	.029	" " "

- PART THREE -

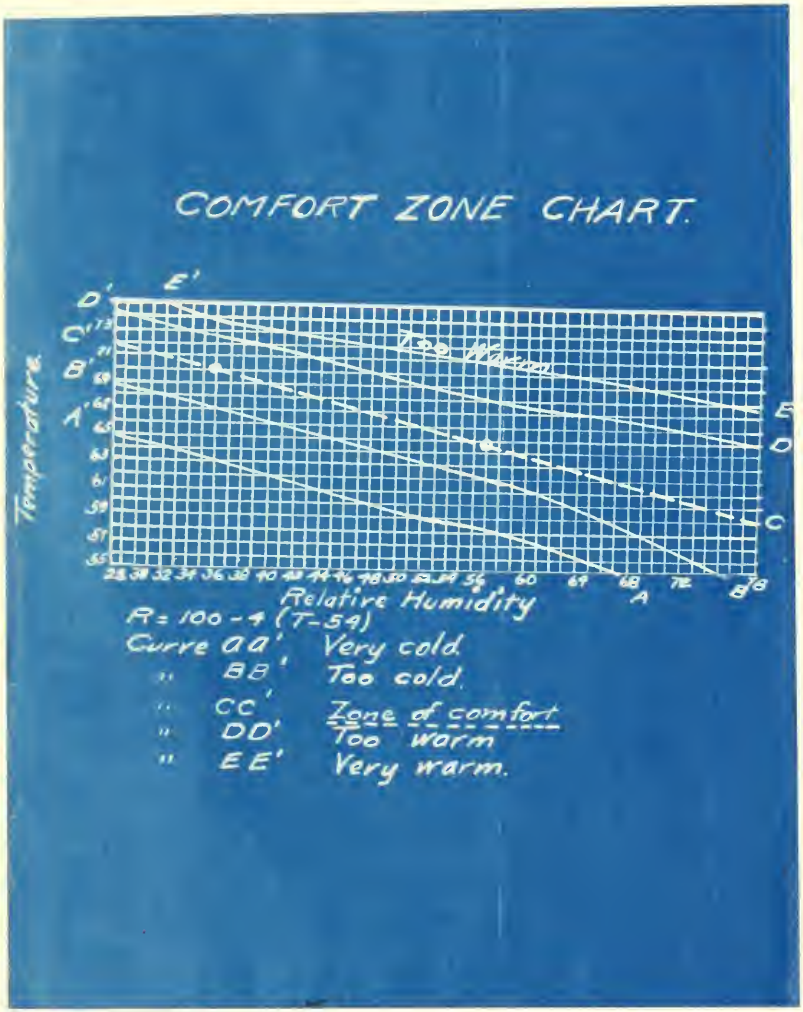
Discussion of the problems involved
in humidifying living rooms.

Introduction.

In the following few pages, the writer has endeavored to show a method for determining the gain or loss in heat units through the humidification of the air in living rooms. There is some doubt in the minds of many Heating and Ventilating experts, as to whether there is any real economy of fuel through humidification, and in order to ascertain this economy, and also to determine the correct amount of water necessary to evaporate to humidify properly, the following method was drawn up.

PART THREE.

In calculating the amount of water that must be added to a room in order properly to humidify it, it is necessary to know, first, the relative humidity of the air drawn into the room, and second, the relative humidity at which we desire to have the room. For our case, we will take an average condition of 70% relative humidity for the air being drawn into the room, and we will take the conditions, as to temperature, the same as in the previous cases, viz., 0° F. outside and 70° F. inside. By a long series of tests at the Chicago Normal College, the Chicago Commission on Ventilation drew up the Chart shown on the following page. In this chart they established what they termed "a zone of comfort," or, in other words, a series of conditions under which the people in a room experienced a feeling of comfort. By taking a look at this chart, we find that for a temperature of 70° a relative humidity of 36% is designated. This is somewhat lower than that given by most auth-


COMFORT ZONE CHART.
D'
E'
C'
B'
A'
Temperature
Lee Wilson
E
D
C
28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 60 64 68 72 78
A
B
Relative Humidity
R = 100 - 4 (T-54)
Curve AA' Very cold.
" BB' Too cold.
" CC' Zone of comfort
" DD' Too warm
" EE' Very warm.

orities, and is lower than the 50% humidity that we have heretofore assumed as necessary. Nevertheless, by using either of the percents given, the amount of water to be evaporated is far in excess of that actually evaporated by any of the humidifiers tested.

Air at 70° temperature, when saturated, contains .001153 lbs. of moisture per cu. ft.

at 50% saturation .000576 lbs.

at 36% " .000417 "

Air taken in at 0° F. contains .000067 lbs. of moisture per cu. ft. At 70% relative humidity the amount of moisture is .0000469.

.000569 - .0000469 = .00053 lbs. per cu. ft.

.000417 -.0000461 = .00037 lbs. per Cu. ft.

This is the amount of moisture in lbs. that must be evaporated in the room for every cu. ft. of air that is brought into the room. Assuming as we did a volume of 2000 cu. ft. for the room, and one change of air per hour, we have:

2000 x .00053 = 1.06 lbs. per hour

2000 x .00037 = .74 lbs. per hour

For 24 hours the amount necessary is

24 x 1.06 = 25.44 lbs. per day

24 x .74 = 17.80 lbs. per day.

One gallon of water weighs approximately 8-1/3 lbs. so that the number of gallons per day is equal to

$$\frac{25.44}{8.33} = 3.06 \text{ gallons}$$

$$\frac{17.80}{8.33} = 2.2 \text{ gallons}$$

This amount, as will be noted, is far beyond the capacity of any humidifier tested. In considering the matter of fuel economy, there are many factors that must be taken into consideration, and they are different in nearly every case. For instance, the coefficient of heat transmission will differ according to the nature of the wall, and according to the proportions of window surface and wall surface. It will also vary according to the position of the room in question; that is, whether it is situated, for instance, on the north side of a building where it will get the direct wind from the north, or in a sheltered position where the

room will be heated much easier. Therefore, as before, it is necessary to take average conditions and average coefficients. In the chart of the Chicago Ventilating Commission, mentioned above, the limit of the "zone of comfort" extends through a point of a temperature of 65° with a humidity of 56%. Taking then, a condition of air drawn into a room of volume of 2000 cu. ft. from an outside temperature of 0° F. and heated up to a temperature of 70° without moisture being added by artificial means, and comparing the amount of heat necessary to raise the temperature of the room to the desired amount, with that necessary to raise the temperature of the room to 65°, with a relative humidity of 56%, the result will give the economy in fuel occasioned by the humidification.

In figuring the heat lost through the walls, the rule laid down by Carpenter in his "Heating & Ventilation" was used, viz.;

$$H = (G + 1/4\ W + 0.02\ V)(t_1 - t_2)$$

where, H = B.t.u. per hour

G = Glass surface in sq. ft.

W = Net exposed wall surface in sq. ft.

V = Volume air supplied per hour

t_2 = temp. air entering

t_1 = temp. air leaving

Assuming a total outside wall surface of 150 sq. ft., of which 100 sq. ft. is wall surface and the remaining 60 sq. ft. window surface, the heat lost by radiation through the wall is

$$H = (60 + \frac{100}{4} + 0.02 \times 2000)(70-0)$$

$$= 8740 \text{ B.t.u. per hour.}$$

Again assuming a complete change of air in the room per hour, the heat necessary to raise the temperature of the air from 0° to 70° is determined by the equation

$$H = \frac{pv}{RT} \times c_p(t_1-t_2)$$

where,

H = B.t.u. per hour

R = Constant (53.5)

T = Absolute temp. of the room

t_2 = temp. air entering room

t_1 = room temp.

Substituting values in this equation

$$H = \frac{14.7 \times 144 \times 2000 \times .24(70-0)}{53.3(460+70)}$$

= 2520 B.t.u. per hour.

The total amount of heat necessary to heat the room to 70° without humidification then is

8740+2520 = 11260 B.t.u.

Now, considering air drawn in at 0°, raised up to a temperature of 65° and humidified to 56°, we find, by using the same formula that we used before, that the heat lost by radiation through the walls is

$$H = (60 + \frac{100}{4} + 0.02 \times 2000)(65-0)$$

= 3125 B.t.u. per hour.

The heat required for ventilation is

$$H = \frac{14.7 \times 144 \times 2000 \times .24(65-0)}{53.3(460+65)}$$

= 2352 B.t.u. per hour.

In addition to the two items above we have the heat used to humidify the air at the temperature of 65°. This amount of heat will be the latent heat of evaporation of the

water at the temperature at which it passes into steam. When water is first put into the humidifier, there will be some heat expended in raising the water up to the point where evaporation takes place, but after this point is reached there will be practically a constant amount of heat necessary to evaporate the water. The water put into the humidifier would probably be at the temperature of the room and the amount of heat necessary to raise it to the temperature of evaporation is insignificant. From a number of actual experiments with the different humidifiers under ordinary pressures, it was found that the average temperature at which the vapor goes off is 95° F. The latent heat of evaporation at 95° is 1038.4 B.t.u. per lb. of water. Then the total amount of heat necessary to maintain the conditions of 65° temperature and humidity 56% is

8125 + 2355 +(1038.4 x .74) = 11258 B.t.u. per hour

In the above formula the .74 lbs. of water was used as the correct amount of water

to be evaporated per hour. This amount would be given under the proportions of temperature and humidity given in Dr. Hill's Comfort Zone Chart mentioned before. We found, however, that to heat the room from zero outside to 70° inside required the expenditure of 11260 B.t.u. per hour. This shows that there is practically no loss or gain through humidification, the amounts being nearly the same. However, air drawn in at zero and heated up to 70° will not have the necessary 36% relative humidity, which was a condition of this temperature being placed in the "zone of comfort." The actual relative humidity would be far below 36%, and if enough moisture was added to the air at this temperature, through the evaporation of water, the heat thus required must be added to the amount necessary to bring the room up to 70°, and this will show a gain on the side of the humidification at 65°.

The actual comparison, however, should be made between a recognized comfortable temperature (not considering whether at this temper-

ature the air has the correct amount of moisture,) and a temperature with a certain humidity. On this basis, 70° was taken as a comfortable temperature, and 65° with a relative humidity of 56% was taken as the desired condition. By the method shown in the preceding pages, the amount of heat necessary to bring the air up to the desired condition was calculated as shown on page 52. By considering the air at various temperatures, we can determine the point at which it is economical to humidify. From the data on the following page, it will be seen that there is a loss in heat units by humidifying when the air is at an outside temperature of from 0° up to 20°. From a temperature of 30° up, there is an increasing gain in economy. From the data of page 54 a curve may be drawn, as indicated on page 55, showing the economy. It must be noted that this curve holds for the room in question alone, and for every room under consideration, in order to obtain correct results, it is necessary first to find the correct coefficient of heat transmission through the walls. This coefficient will

B.T.U. NECESSARY TO PROPERLY HUMIDIFY AT 65°

FROM VARIOUS OUTSIDE TEMPERATURES.

Outside Temperature	lbs/cu.ft. moisture 70% H	lbs/cu.ft. moisture 65° T 56% H	Difference per cu.ft.	Moisture necessary 2000 cu.ft.	B.T.U. to evaporate
0	.0000469	.000542	.000495	.99	1028
10	.0000768	"	.000465	.93	965
20	.000124	"	.000418	.836	868
30	.000182	"	.000360	.72	747
35	.000248	"	.000294	.588	610
40	.000287	"	.000255	.510	530
45	.000344	"	.000198	.39	405
50	.000410	"	.000132	.264	274

B.T.U. NECESSARY FOR HEATING TO 65°

WITH HUMIDIFICATION.

Temperature	B.T.U. per hour			
	Radiation	Ventilation	Humidification	Total
0	8125	2355	1028	11508
10	6875	1995	965	9835
20	5625	1635	868	8128
30	4370	1291	747	6408
35	3750	1090	610	5450
40	3130	907	530	4507
45	2500	726	405	3631
50	1875	544	274	2693

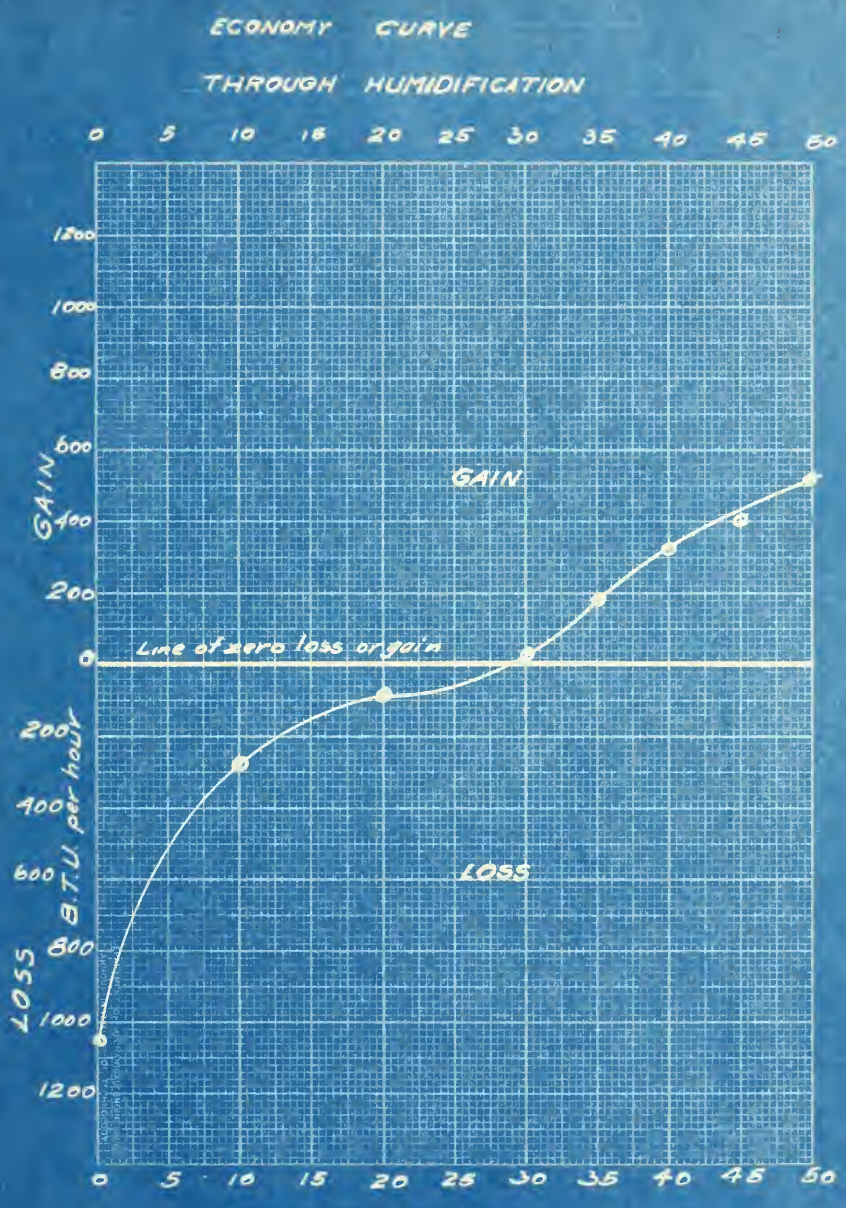
B.T.U. NECESSARY FOR HEATING TO 70°
WITH VARIOUS OUTSIDE TEMPERATURES.

Temperature	B.T.U. per hour		
	Radiation	Ventilation	Total
0	8125	2320	10445
10	7500	2155	9655
20	6250	1795	8045
30	5000	1439	6439
35	4370	1260	5630
40	3750	1070	4820
45	3130	900	4030
50	2500	720	3220

B.T.U. LOSS OR GAIN

THRU HUMIDIFICATION.

Outside Temperature	Total B.T.U. without Humidification	Total B.T.U. with Humidification	Loss	Gain
0	10445	11508	1063	
10	9655	9835	280	
20	8045	8128	83	
30	6439	6408		31
35	5630	5450		180
40	4820	4507		313
45	4030	3631		399
50	3220	2693		527


ECONOMY CURVE
THROUGH HUMIDIFICATION
0 5 10 15 20 25 30 35 40 45 50
1200
1000
800
600
400
200
0
200
400
600
800
1000
1200
GAIN
LOSS
B.T.U. per hour
GAIN
Line of zero loss or gain
LOSS
0 5 10 15 20 25 30 35 40 45 50
DEGREES TEMPERATURE OUTSIDE

also vary with the wind, etc., as previously mentioned. However, the curve shown on page 55 gives the economy of the average room, and its general form is that of all curves showing fuel economy.

- PART FOUR -

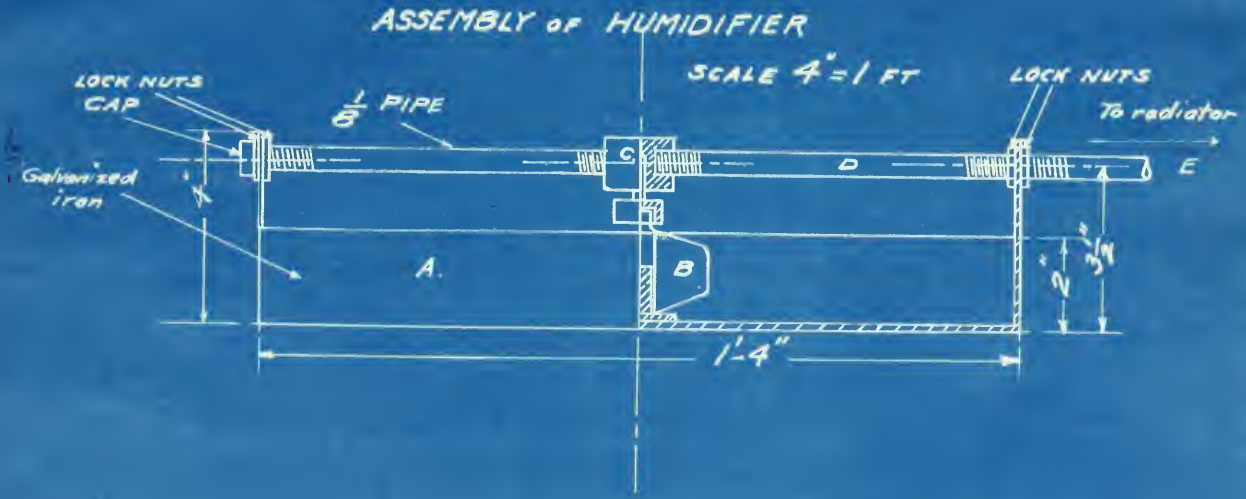
Design of a
proposed humidifier.

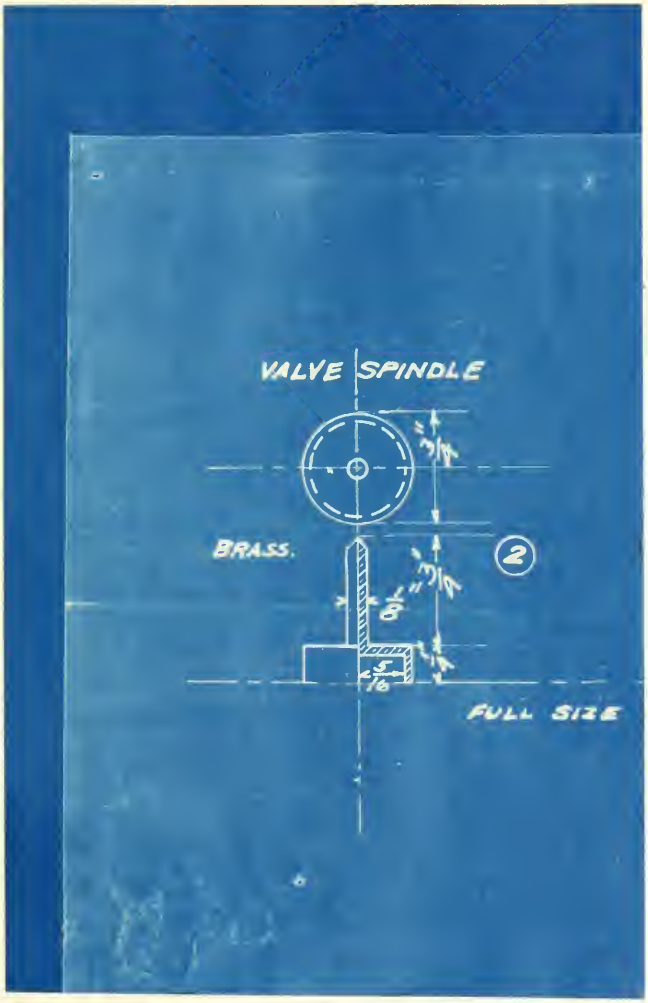
Introduction.

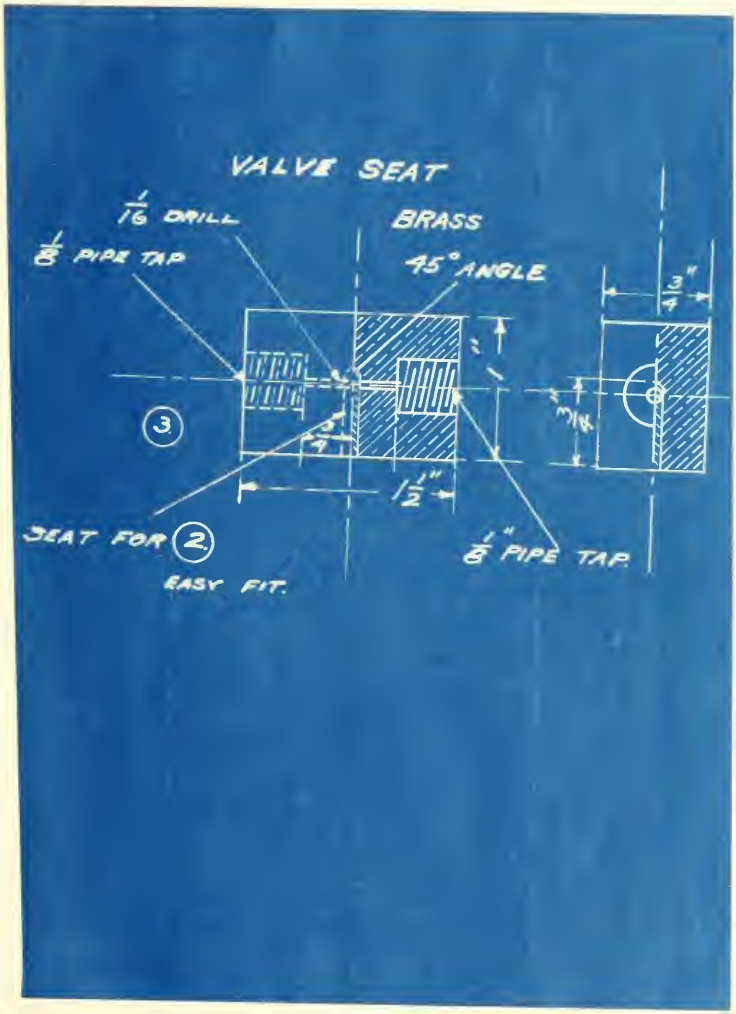
From the tables shown in Part Three it is seen that the loss or gain through humidification is largely determined by the amount of water necessary to be evaporated to obtain the desired humidity, and in the design shown in the following pages the main idea is to get the moisture into the atmosphere without first condensing it and in this way retain the heat that would be necessary to evaporate the moisture from the liquid state.

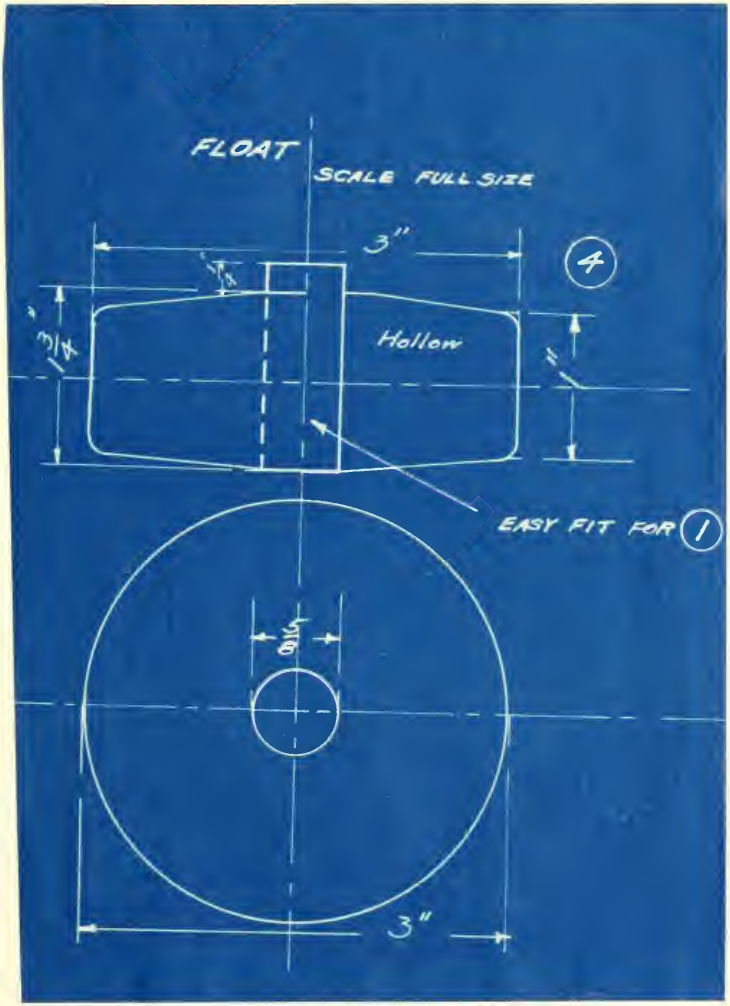
PART FOUR.

The amount of heat necessary to evaporate the water to moisten the air is the item that makes the economy of humidification questionable. As was shown, the latent heat of evaporization of water at 95° is 1034.4 B.t.u. per lb. of water, or, in other words, it takes 1034.4 B.t.u. to evaporate 1 lb. of water at a temperature of 95°. If then, we can get away from this item of changing the water into vapor, the economy, through humidification, is assured. With this idea in view, the apparatus shown on the following page was designed and constructed. The principal feature of this humidifier is the moistening of the air by taking the moisture direct from the steam in the radiator. It consists of a pan A to hold the condensed steam, a float B to automatically close the valve at C, and a steam passage D from the radiator. In constructing the apparatus, it was the intention to make it with the view of getting the action of the valve, and to find out if the general idea were of value, and the pan, as made, was merely to


ASSEMBLY of HUMIDIFIER
SCALE 4" = 1 FT
LOCK NUTS
CAP
1/8 PIPE
LOCK NUTS
To radiator
Galvanized iron
A.
B
C
D
E
2"
3 1/2"
1'-4"


VALVE SPINDLE
BRASS.
2
FULL SIZE


VALVE SEAT
1/16 DRILL
BRASS
1/8 PIPE TAP
45° ANGLE
3/4"
3
1/2"
SEAT FOR 2
EASY FIT.
1/8" PIPE TAP.


FLOAT
SCALE FULL SIZE
3"
4
Hollow
EASY FIT FOR 1
3"


FLOAT GUIDE
BRASS
FULL SIZE

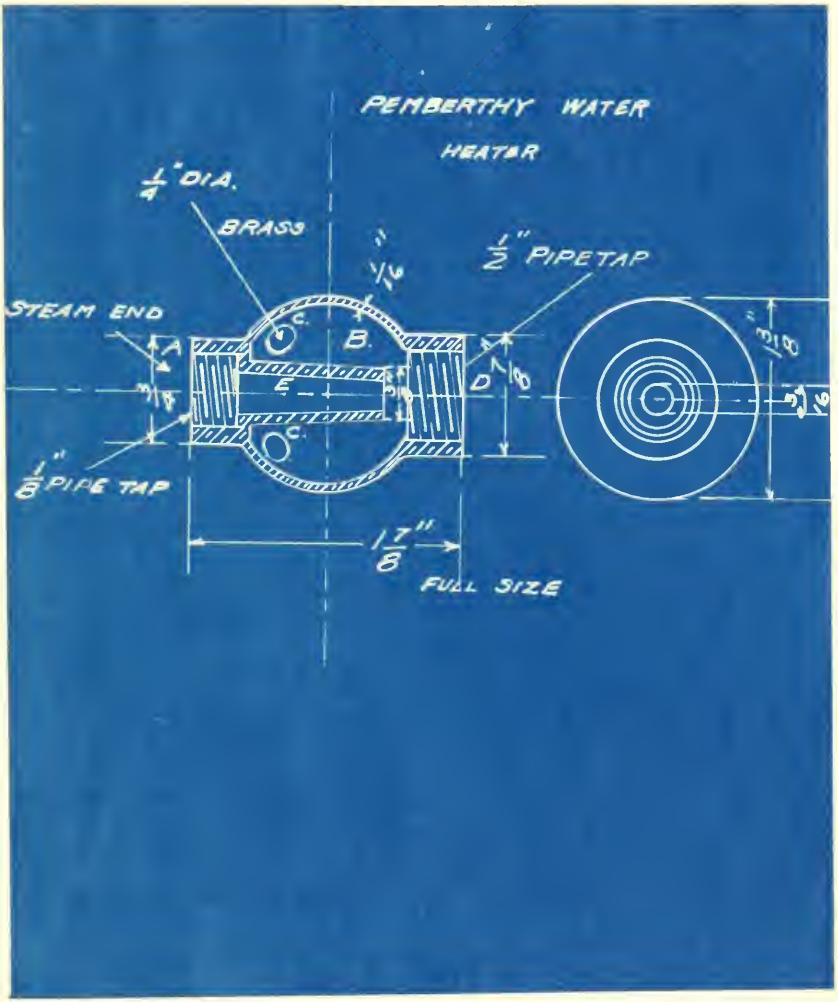
hold a sufficient amount of water to float the valve. The size and capacity shown is not that which would be necessary for a humidifier in practice. The method of operation is as follows: The steam enters the passage D from a hole tapped in the radiator at E. This hole may be tapped in any place in the end of the radiator. In many cases there is already a hole tapped in, filled in with a plug, and this may be utilized by making suitable connections. The steam passes through D and into the valve C. As it passes through D, part of the steam is condensed, and the steam and water pass out through the valve C, the water running over the float F into the pan A. The moisture in the steam passes directly into the air, and in this manner does not take up an amount of heat equal to the latent heat of evaporation. On each side of the valve, extending up over the stays, and dipping down into the water in the pan, is a cloth wick to draw the water up and aid in the moistening of the air by evaporation. When the water gets to a definite level in the pan,

the float B raises, and the valve C is closed automatically. When enough water has been evaporated from the wick to lower the float, the valve C again opens and water and steam pass out and over the float.

In operation, however, it was found that the valve C required very fine adjustment in order to work properly. If its seat was the least bit out of line, or the spindle of the valve had a bearing on one side it would stick, and the valve would not close properly. The seat would have to be made absolutely rigid, and the construction of the apparatus as a whole would necessitate a high degree of mechanical skill. Considering the conditions in a household under which a humidifier must operate, it was quickly seen that this type was not practical. A humidifier, to be a success, must require little if any care, and with the apparatus as described above, it requires very little imagination to see that it would be out of commission a greater part of the time. If a valve can be designed to

work regularly, and is simple of construction, the above form would be sufficient and economical.

Experiments were made in order to see if it would be possible to humidify by means of an apparatus somewhat similar in form to the one shown on the following page. This is an apparatus for heating water by running steam into it. Ordinarily, when steam is run into water, there is a loud cracking and bubbling sound, but with this device the noise is eliminated. The principle is as follows: The steam enters through the passage A, and in passing through F sucks in water through the holes C. The water and steam together pass out into the vessel D through the nozzle E. The action of the water on the sides of the nozzle seems to eliminate a great deal of the friction, and the steam enters the water with very little noise. If this same principle could be applied to air, it would be a simple matter to humidify the air by admitting steam direct into it from the radiator. The objection to doing this is the noise of the escaping steam, and the scatter-


PEMBERTHY WATER
HEATER
1/4" DIA.
BRASS
1/2" PIPE TAP
STEAM END
A
B.
C.
C.
E
D
1/8" PIPE TAP
1 7/8"
FULL SIZE

of particles of water in the vicinity of the nozzle. However, this form when used in air does not eliminate the noise, but by varying the size and shape of the nozzle, and the size and number of the openings for the water to pass through, a device might be made which would be as satisfactory for air as the one on the previous page is for water. Time, however, did not permit the writer to design and construct a nozzle of this kind. If a nozzle of this kind can be made to eliminate the noise, there will still be the feature of the scattering of water particles to be done away with. The device must be made so that the water will drain back into the radiator or go to a waste pipe. On account of the pressure in the [illegible] it would [illegible] practical to figure on returning it there under a pressure head of water, as with a pressure of from 3 to 5 lbs. a head of from 4 to 6 ft. would be necessary. There is also to be considered the fact that many times when a radiator has had [illegible] filled up with water, and when the steam was turned on again it would

tend to shove the water out through the humidifier. As a whole it offers an interesting problem to anyone of an inventive nature, and it is not without the possibility of satisfactory solution.

SUMMARY.

As a short summary of the conclusions from the experiments performed, it may be said that first of all the humidifier, to be satisfactory, must be made to operate with little or no attention. This eliminates, at once, any apparatus that does not work automatically. Any humidifier that depends for its operation on a continual refilling cannot be considered entirely satisfactory.

In order to operate with any saving of fuel, a humidifier operating on the basis of the evaporation of water for the moistening of the air, must be in use only when the outside temperature is above 30° F. It has also been shown that the humidifiers on the market do not evaporate enough water to moisten the air in a room to a sufficient degree, and are practically worthless.

Finally, a method of humidification is proposed, which will require a great deal of experimental work before a successful design can be

made. However, it opens up an interesting field, and it is hoped that some future work in this idea may be carried through to a successful culmination.

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